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ENTOMOLOGICAL PHASES OF THE 1961 LODGEPOLE NEEDLE MINER CONTROL PROJECT IN YOSEMITE NATIONAL PARK

By

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U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION

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PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
Division of Forest Insect Research

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SUMMARY

During the summer of 1961, the Yosemite National Park carried on an aerial spraying program to control the lodgepole needle miner in the Tuolumne Meadows-Tenaya Lake area. A total of 4,928 acres of lodgepole pine out of an aggregate of more than 60,000 infested acres was sprayed July 13 to 18. The insecticide, malathion, was applied with helicopters at the rate of 1 pound in 10 gallons of diesel oil per acre. The spray was directed against the adult stage, and was aimed at reducing the moth population before the females had a chance to oviposit.

The principal entomological jobs were (1) to determine when the population reached the proper stage of development for spraying, and (2) to measure the degree of control attained. This work was done by the Experiment Station, which assisted the Park on the technical phases of the project.

Needle miner development during the late larval, pupal, and early adult stages was determined by daily sampling throughout the control area, from June 6 to August 4. Spraying began as planned when about one-quarter of the needle miners reached the adult stage, and when it ended three-quarters of them were in this stage. The target date for starting spraying was accurately predicted from the sampling data 1 month in advance.

The treatment reduced the population drastically in most of the area sprayed. Pre- and postcontrol sampling at selected stations in sprayed and unsprayed areas showed 90 percent control (corrected for natural mortality). Sequential sampling, also used to measure the effects of the spray, showed 98 percent of the plots in the "light infestation" category after spraying, as opposed to only 22 percent in the category before spraying. Sampling during the egg stage indicated 91 percent fewer eggs in the sprayed areas than in the unsprayed ones.

In the area sprayed, the number of needle miners generally was reduced to a level which is not expected to be capable of causing topkilling or tree mortality for at least 4 years.

INTRODUCTION

In 1959 plans were laid for spraying a portion of the lodgepole pine forests in the headwaters of the Tuolumne River in Yosemite National Park, California, to protect these forests from a severe outbreak of the lodgepole needle miner, Evagora milleri (Busck). Part of the designated area was sprayed in 1959 with malathion applied by helicopter.[1/][2/] The remainder was sprayed during 1961, and it is the entomological details of the 1961 project with which this report is concerned.

In the main, the 1961 project was much like that of 1959. The insecticide was applied by helicopter, and the formulation used, 0.1 pound malathion per gallon of diesel oil, was the same. Two significant modifications, however, were the reduction of the insecticide dosage by one-half, from 20 to 10 gallons to the acre, and the direction of the entire effort against the moths. In the previous project, part of the area was sprayed to control the moths, and the remainder to control the first-instar larvae of the succeeding generation.

The operational phases of the 1961 project were carried out by the Yosemite National Park, and technical assistance on the entomological portion of the work was furnished by the Division of Forest Insect Research, Pacific Southwest Forest and Range Experiment Station, U. S. Forest Service. The writer was in charge of the Station's part of the work, and was assisted in many of its field phases by Charles Sartwell, Jr., and Michael E. Schymeinsky. George R. Struble served in the capacity of consultant on biological phases of the work, and assisted in the precontrol survey, as did Eric Jessen. Struble also directed the egg sampling. Boyd E. Wickman, Thomas W. Koerber, and William D. Bedard, all from the Station, and George L. Downing, Division of Timber Management, U. S. Forest Service, San Francisco, assisted in the post-control survey. Charles O'Brien, a specialist in insect taxonomy, segregated and identified other insects that were killed by the spray.

The Station's primary responsibilities, spelled out in detail in the plan for the entomological phases of the project,[3/] were as follows:

1. Designate from the entomological standpoint the areas requiring treatment.

1/ Stevens, Robert E. and Struble, George R. 1960. Entomological phases of the 1959 lodgepole needle miner control project in Yosemite National Park. U. S. Forest Serv., Pacific Southwest Forest and Range Expt. Sta., Berkeley, Calif. 27 pp., illus. (processed).

2/ Sharp, Robert H. and Smith, Robert J. 1960. Insect control section, annual forestry report of Yosemite National Park for the calendar year 1959. 17 pp., illus. (typed).

3/ Stevens, Robert E. 1961. Plan for the entomological phases of 1961 lodgepole needle miner control work in Yosemite National Park. U. S. Forest Serv., Pacific Southwest Forest and Range Expt. Sta., Berkeley, Calif. 8 pp. (processed).

2. Specify the insecticide and dosage to be used.

3. Time the spray application for maximum effectiveness.

4. Determine the effectiveness of the treatment.

5. Cooperate with the Park on such other details as necessary.

The following sections of this report tell how these responsibilities were carried out.

SPRAY AREAS

The lodgepole pine stands where the needle miner control project was conducted are included in a large infestation exceeding 60,000 acres in size, which has been in progress for more than a decade. The gross area originally programmed for control was approximately 10,000 acres, and in 1959 some 3,400 acres of this total were sprayed. To a large extent the area treated in 1961 consisted of the parts of the 10,000 acres delineated in 1959 that were not treated that year. Some of the spraying in 1961 was to retreat areas sprayed in 1959, in which insect populations and damage were still severe. The areas resprayed amounted to about one-fifth of the total.

The criteria used by the Park for choosing the areas to be sprayed were (1) the amount of development and intensity of public use of the areas involved, (2) the current status and expected course of the infestation, and (3) the threat posed by infested areas to existing or potential high-use areas nearby.

Reconnaissance to outline the areas in which needle miner populations were heavy enough to justify control was done in the fall of 1960. Using this information, Park Service and Station representatives met in January 1961 to discuss plans for the project and to outline generally the areas to be treated. The detailed work of laying out control units on aerial photos and determining the acreages was then done in Berkeley between February and June.4/ Final groundchecking of these units was done in the field in June and July 1961; later some modifications and additions to the boundaries of the units were made for operational reasons as the spraying progressed.

The generalized area treated is shown in figures 1 and 2. Outline maps showing in detail the areas treated are on file at the Division of Forest Insect Research, Pacific Southwest Forest and Range Experiment Station.

4/ For the mechanics of these procedures see Stevens and Struble, op. cit., p. 6.

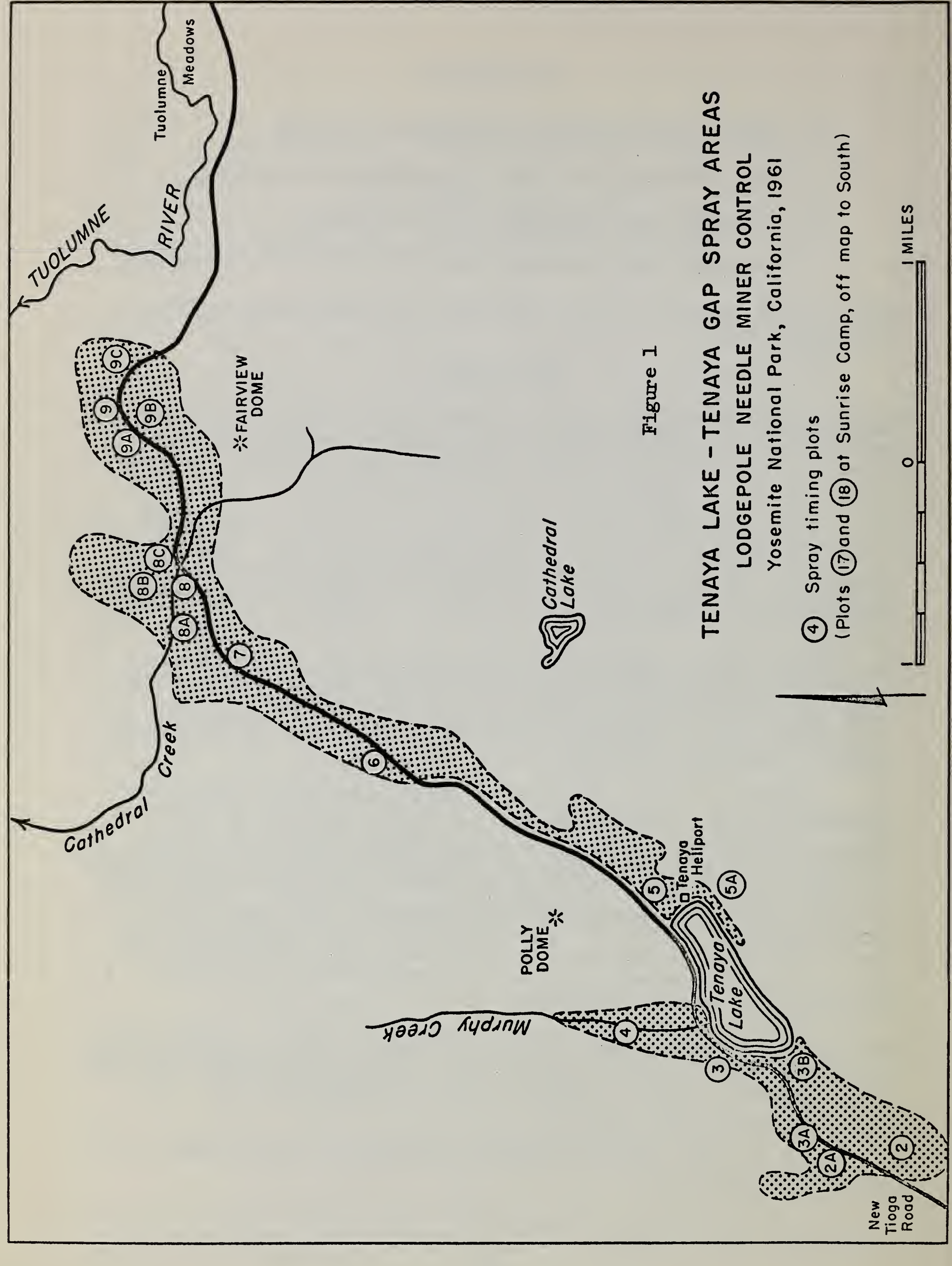

Figure 1

TENAYA LAKE - TENAYA GAP SPRAY AREAS

LODGEPOLE NEEDLE MINER CONTROL

Yosemite National Park, California, 1961

4 Spray timing plots

(Plots 17 and 18 at Sunrise Camp, off map to South)

Figure 2
TUOLUMNE MEADOWS SPRAY AREAS
LODGEPOLE NEEDLE MINER CONTROL
Yosemite National Park, California, 1961

(14) Spray timing plots
(Plots (17) and (18) at Sunrise Camp, off map to South)

INSECTICIDE AND STAGE OF INSECT SPRAYED

The spray material used in the 1961 operation was malathion dissolved in diesel oil at the rate of 0.1 pound per gallon. It was applied at the rate of 10 gallons per acre, and the application was timed to control the moths.

The decision to apply half the dosage used in 1959, and to direct the entire operation against the moths instead of against both moths and larvae, was made at the Berkeley meeting of Park Service and Forest Service representatives in January. It was motivated by a number of factors. Field tests in 1957, in which the malathion formulation was tried against the moths, had shown little difference in the degree of control attained with the 10-and 20-gallon treatments. Up to 1959, these results were not considered to be too significant because they were based on very limited trials. However, the moth spraying in 1959 with 20 gallons of insecticide per acre caused a population reduction of nearly 90 percent. This was considerably better than the 70 percent held to be adequate to protect the trees, and it provided some margin for reducing the quantity of spray while still maintaining an acceptable level of control. Additional evidence suggesting a reduced dosage was obtained from spray-chamber tests conducted against the overwintering larvae, which showed the 10-gallon dosage to be about as effective as the 20-gallon dosage.[5/]

Results of the 1959 project showed that spraying against the moths was clearly superior to spraying against the larvae. Confining the 1961 work to the moth stage made it necessary to treat the entire area in no more than half the time available for treating both stages. There was some question whether a sufficient number of helicopters would be available to do the job if a dosage lower than 20 gallons per acre was not used. Both of these considerations favored using a lower dosage. Other factors leading to this decision were reduced costs in the case of the lighter treatment, and the desirability of using as small an amount of insecticide as possible to minimize side effects.

SPRAY TIMING

The plan for the work specified beginning treatment when 25 percent of the moths had emerged. Observations made in connection with the 1959 control project had established that males predominate during the early part of the emergence period, and that only 5 percent of the females would have emerged when the total emergence reached the 25 percent level. Thus, oviposition would be negligible when this occurred.

5/ Lyon, Robert L. 1962. Insecticides for controlling the lodgepole needle miner. Part I. Laboratory spray-chamber test of selected insecticides. Part II. Review of field-spraying operations. Progress Report. U. S. Forest Serv., Pacific Southwest Forest and Range Expt. Sta., Berkeley, Calif. (in preparation).

In order to give the Park a date around which to plan, July 15 was established early in the year as the tentative date when spraying reasonably could be expected to begin. Thirty days in advance, a prediction of the date for starting the operation was made based on the pupation rate; then the 5-day notice was given when 1 percent of the moths had emerged. The 30-day prediction was based on the knowledge that the needle miner spends about 1 month in the pupal stage. Thus, when 25 percent pupation occurred, it was expected that the date to begin spraying would be 30 days thereafter. The 5-day notice was predicated on the expectation that the 1961 population of moths would emerge at about the same rate as in 1959.

To provide data for these predictions and subsequently to help guide the sequence of treating the different spray blocks, a basic series of 16 sample plots was established throughout the area during the first 2 weeks of June (figures 1 and 2). On each plot one infested tip from the midcrown (or about 18 feet above the ground) of each of 10 trees was collected periodically, and from these samples the estimate of the percent of the population in each stage of development (larvae, pupae, or moths) was obtained. The tips were put in plastic bags as they were collected and were taken to the field laboratory, where 10 infested needles were pulled from each one, for a total of 100 infested needles. Then the developmental stage of the insect in each needle was determined by eye or with the use of a binocular microscope. With 100-needle samples the number of needle miners in each stage was the percentage in that stage at that location on that particular date.

Sampling according to this procedure was begun on June 6 and continued nearly every day until August 4. However, all plots were not sampled each day, and data were obtained from a number of other plots in addition to the 16 more or less regularly checked. During periods when most of the insects remained in one stage (e.g., pupae), the time between samplings at a particular location in a number of cases amounted to 5 to 7 days. When the changes from larvae to pupae and pupae to adults were first noted, however, samples were taken more frequently on the regular plots and the data from these were augmented by establishing additional plots. Excluding the few times when no samples were taken, the number of insects examined in a day for this phase of the work varied from 100 to 1,400 and averaged about 540. The data for each day's samples are presented in table 9 (appendix), and the pooled daily percentages of the population in each stage are given in table 1 and figure 3. Similar information for seven representative individual locations is presented in figures 4 to 10.

On June 14, the number of pupae in the 700 infested needles examined reached 18.9 percent. The rate of pupation then was rising rapidly, and considering the pattern of the 1959 moth emergence, it was predicted that the target date for starting spraying would fall 30 days hence. The accuracy of this prediction is indicated by the data in table 1,

Table 1.--Developmental stages of the lodgepole needle miner population on different dates, June to August 1961[1/]

Date	Number insects examined	Larvae: Number	Larvae: Percent	Pupae: Number	Pupae: Percent	Adults: Number	Adults: Percent
June 6	500	500	100.0	--	--	--	--
7	100	100	100.0	--	--	--	--
8	900	900	100.0	--	--	--	--
9	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--
11	--	--	--	--	--	--	--
12	--	--	--	--	--	--	--
13	800	769	96.1	31	3.9	--	--
14	700	568	81.1	132	18.9	--	--
15	1,000	689	68.9	311	31.1	--	--
16	800	383	47.9	47	52.1	--	--
17	--	--	--	--	--	--	--
18	--	--	--	--	--	--	--
19	1,200	297	24.7	903	75.3	--	--
20	400	35	8.7	365	91.3	--	--
21	600	56	9.3	544	90.7	--	--
22	400	27	6.7	373	93.3	--	--
23	500	41	8.2	459	91.8	--	--
24	--	--	--	--	--	--	--
25	--	--	--	--	--	--	--
26	400	14	3.5	386	96.5	--	--
27	300	5	1.7	295	98.3	--	--
28	400	16	4.0	384	96.0	--	--
29	500	37	7.4	463	92.6	--	--
30	400	14	3.5	386	96.5	--	--
July 1	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--
3	500	14	2.8	486	97.2	--	--
4	500	18	3.6	482	96.4	--	--
5	300	3	1.0	297	99.0	--	--
6	600	11	1.8	586	97.7	3	0.5
7	500	3	0.6	492	98.4	5	1.0
8	800	8	1.0	763	95.3	29	3.7
9	800	7	0.9	730	91.2	63	7.9
10	1,400	15	1.1	1,250	89.3	135	9.6
11	1,000	10	1.0	818	81.8	172	17.2
12	1,000	4	0.4	723	72.3	273	27.3
13	1,200	--	--	870	72.5	330	27.5
14	700	--	--	417	59.6	283	40.4
15	500	--	--	306	61.2	194	38.8

Table 1.--Continued

Date	Number insects examined	Larvae: Number	Larvae: Percent	Pupae: Number	Pupae: Percent	Adults: Number	Adults: Percent
July 16	2/ 200	--	--	185	92.5	15	7.5
17	400	--	--	183	45.7	217	54.3
18	500	--	--	115	23.0	385	77.0
19	300	--	--	54	18.0	246	82.0
20	400	--	--	137	34.2	263	65.8
21	300	--	--	49	16.3	251	83.7
22	--	--	--	--	--	--	--
23	--	--	--	--	--	--	--
24	400	--	--	45	11.2	355	88.8
25	300	--	--	37	12.3	263	87.7
26	300	--	--	34	11.3	266	88.7
27	300	--	--	26	8.7	274	91.3
28	200	--	--	11	5.5	189	94.5
29	--	--	--	--	--	--	--
30	--	--	--	--	--	--	--
31	300	--	--	13	4.3	287	95.7
Aug. 1	100	--	--	7	7.0	93	93.0
2	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--
4	100	--	--	18	18.0	82	82.0

1/ Condensed from table 9, appendix.

2/ All samples from Sunrise Camp, where development was considerably slower than in the main spray area.

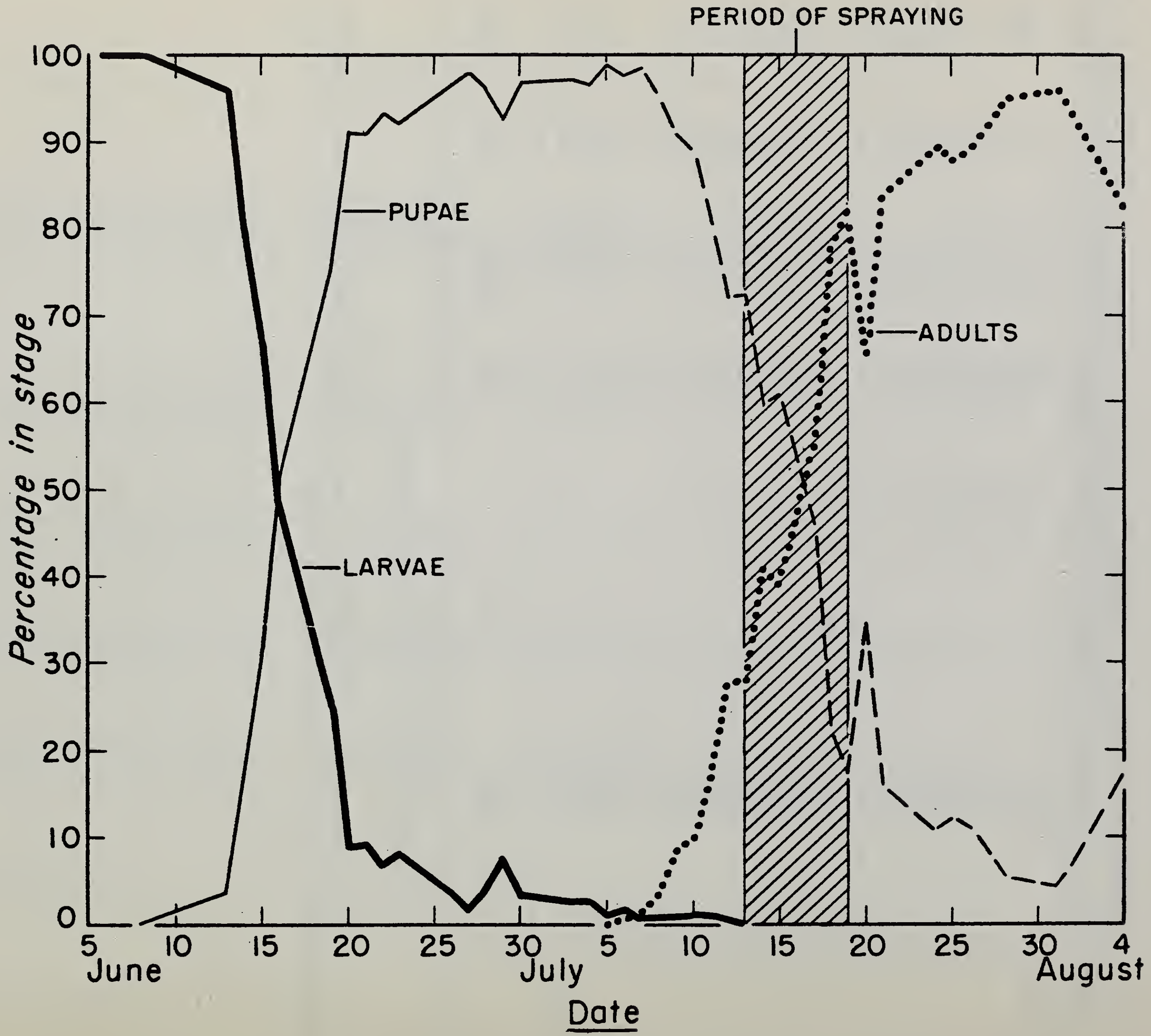

Figure 3.--Pooled needle miner development from all spray timing plots.

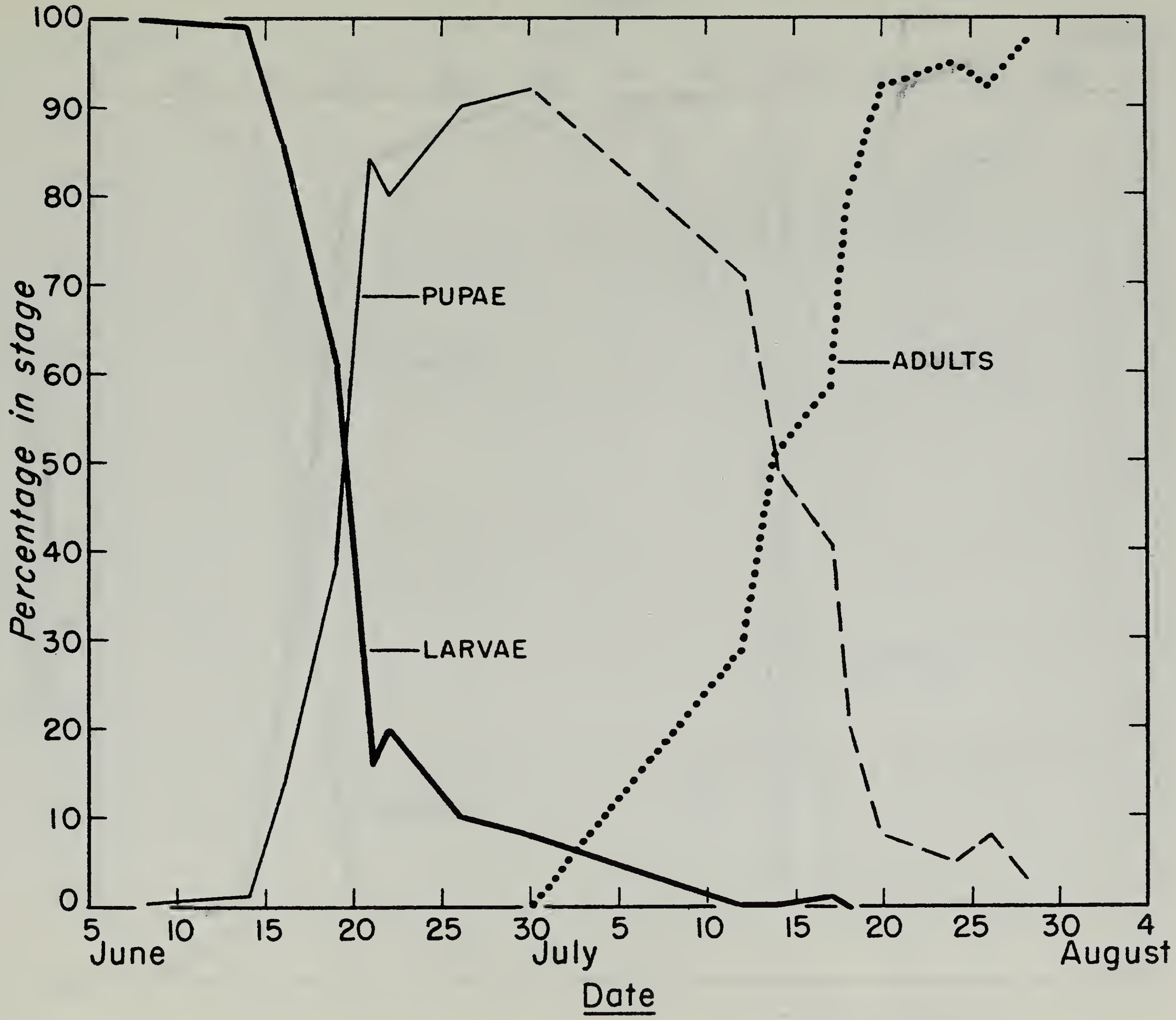

Figure 4.--Needle miner development at spray timing plot 1.

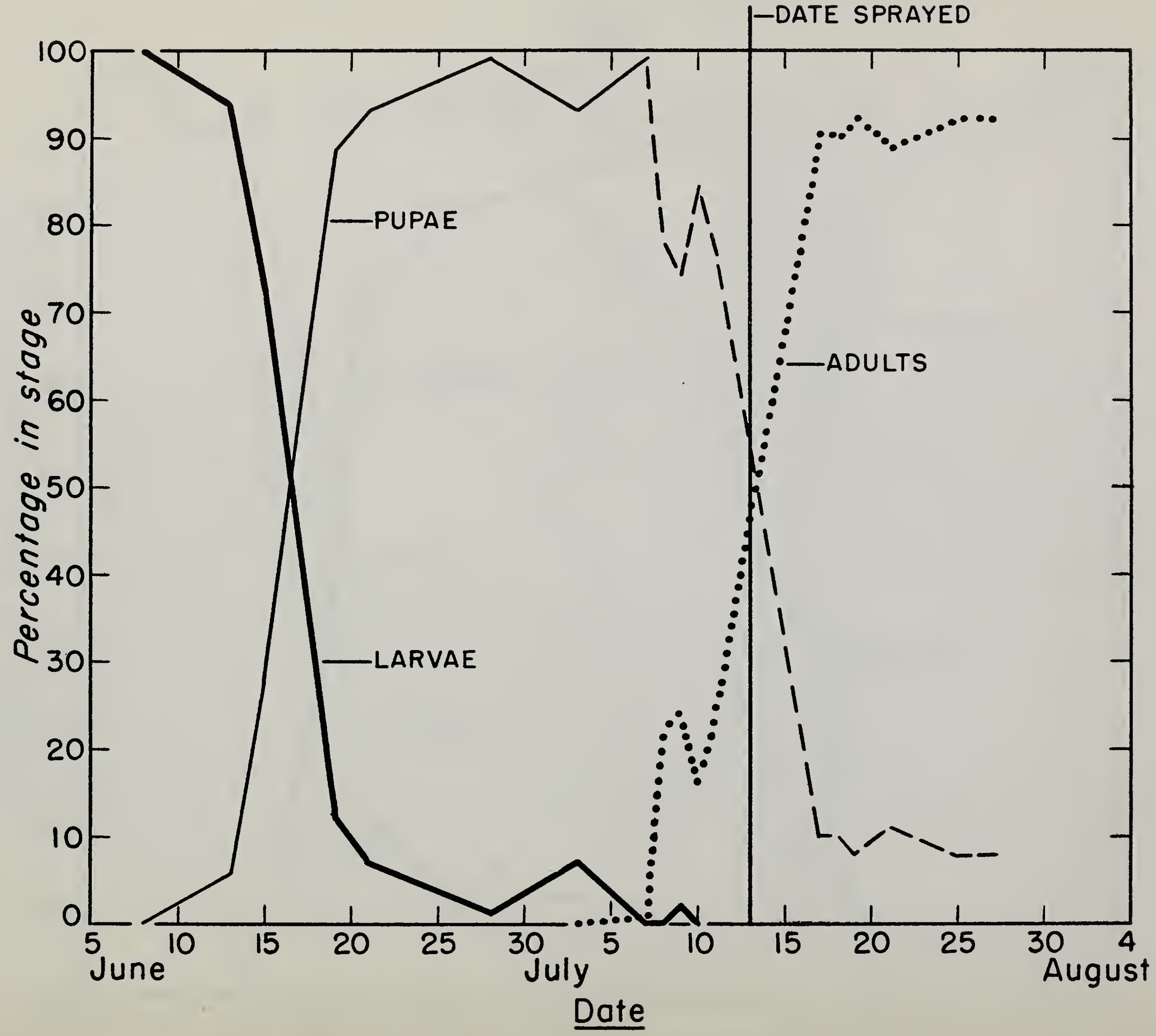

Figure 5.--Needle miner development at spray timing plot 3.

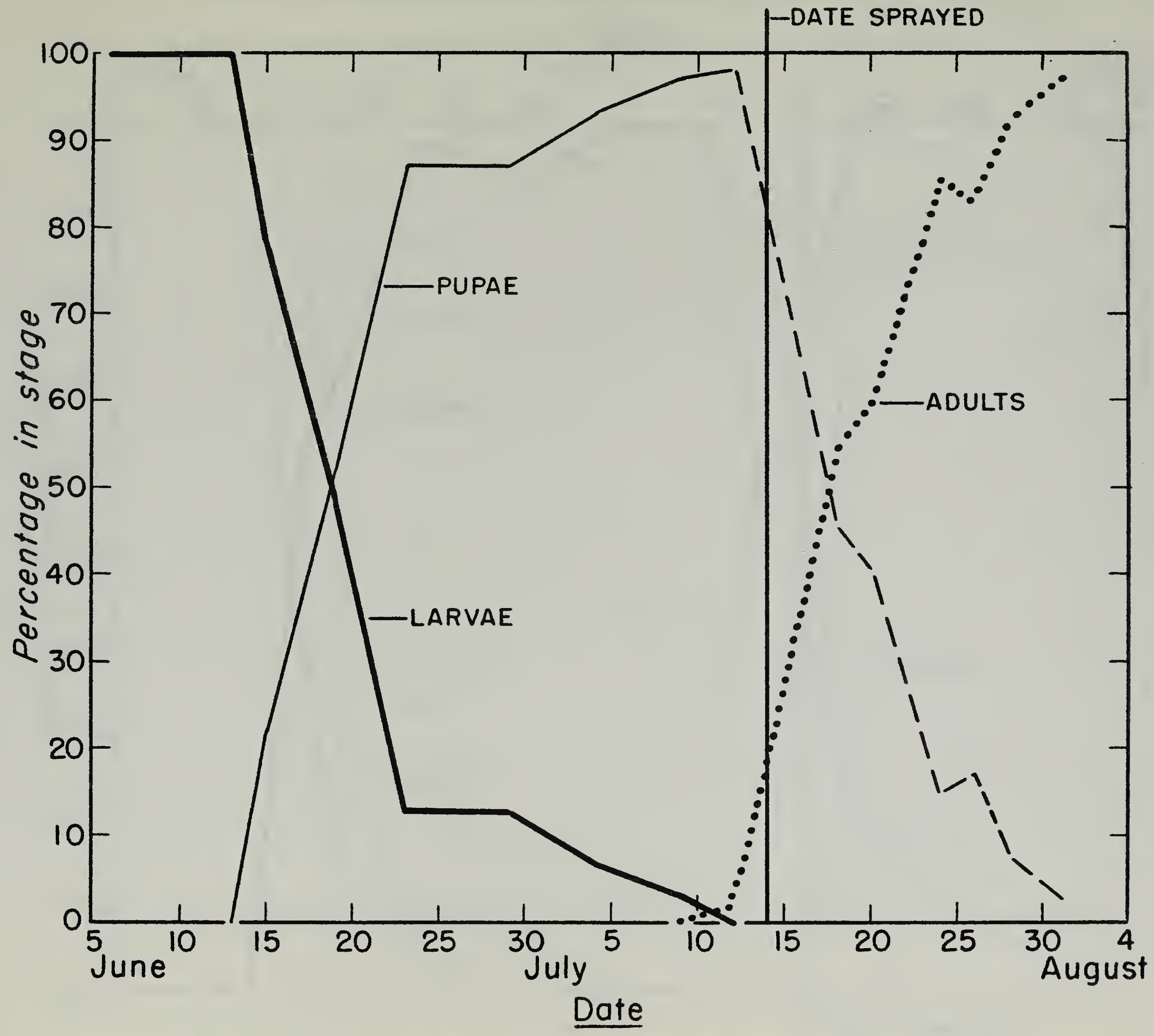

Figure 6.--Needle miner development at spray timing plot 6.

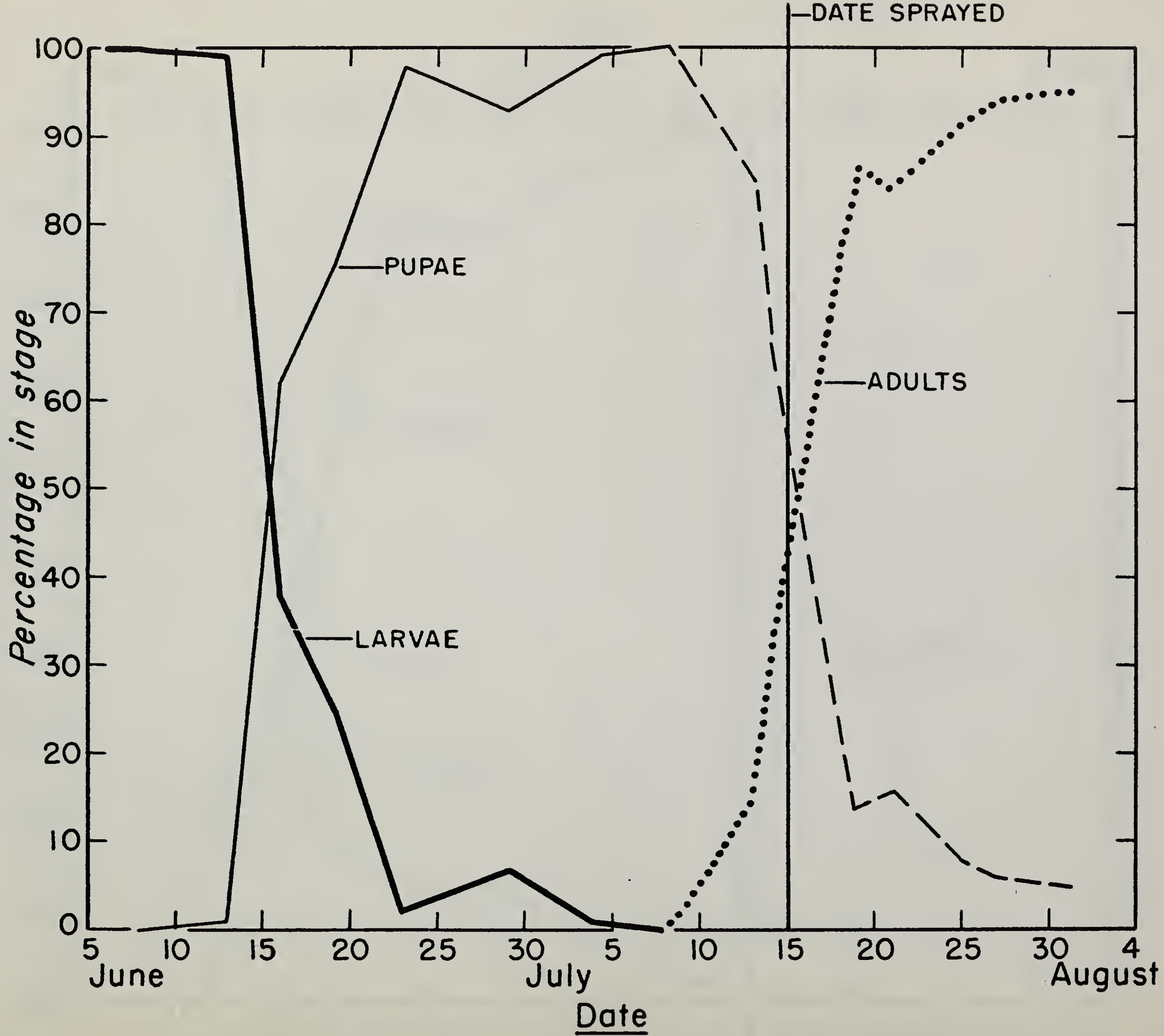

Figure 7.--Needle miner development at spray timing plot 7.

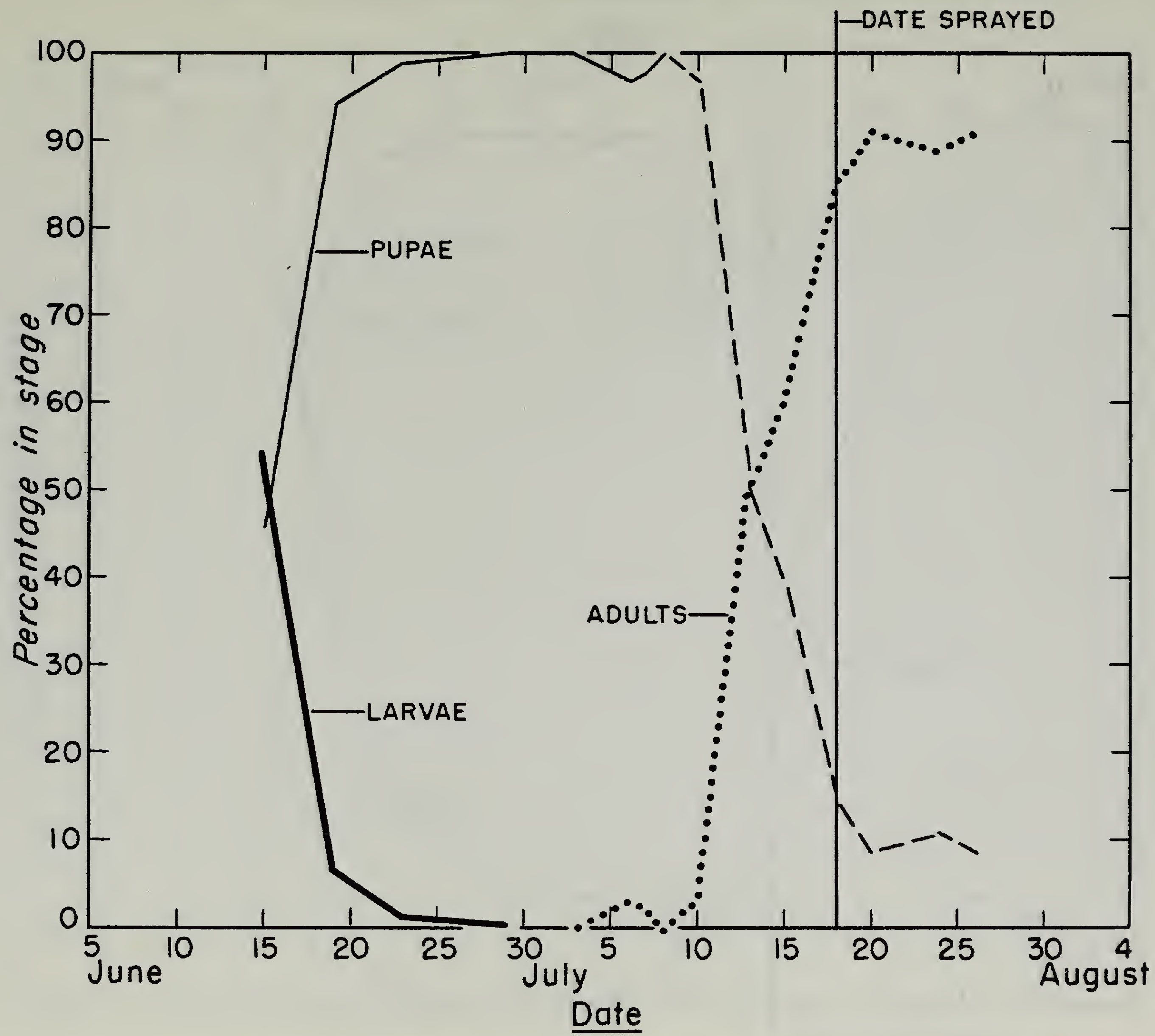

Figure 8.--Needle miner development at spray timing plot 11.

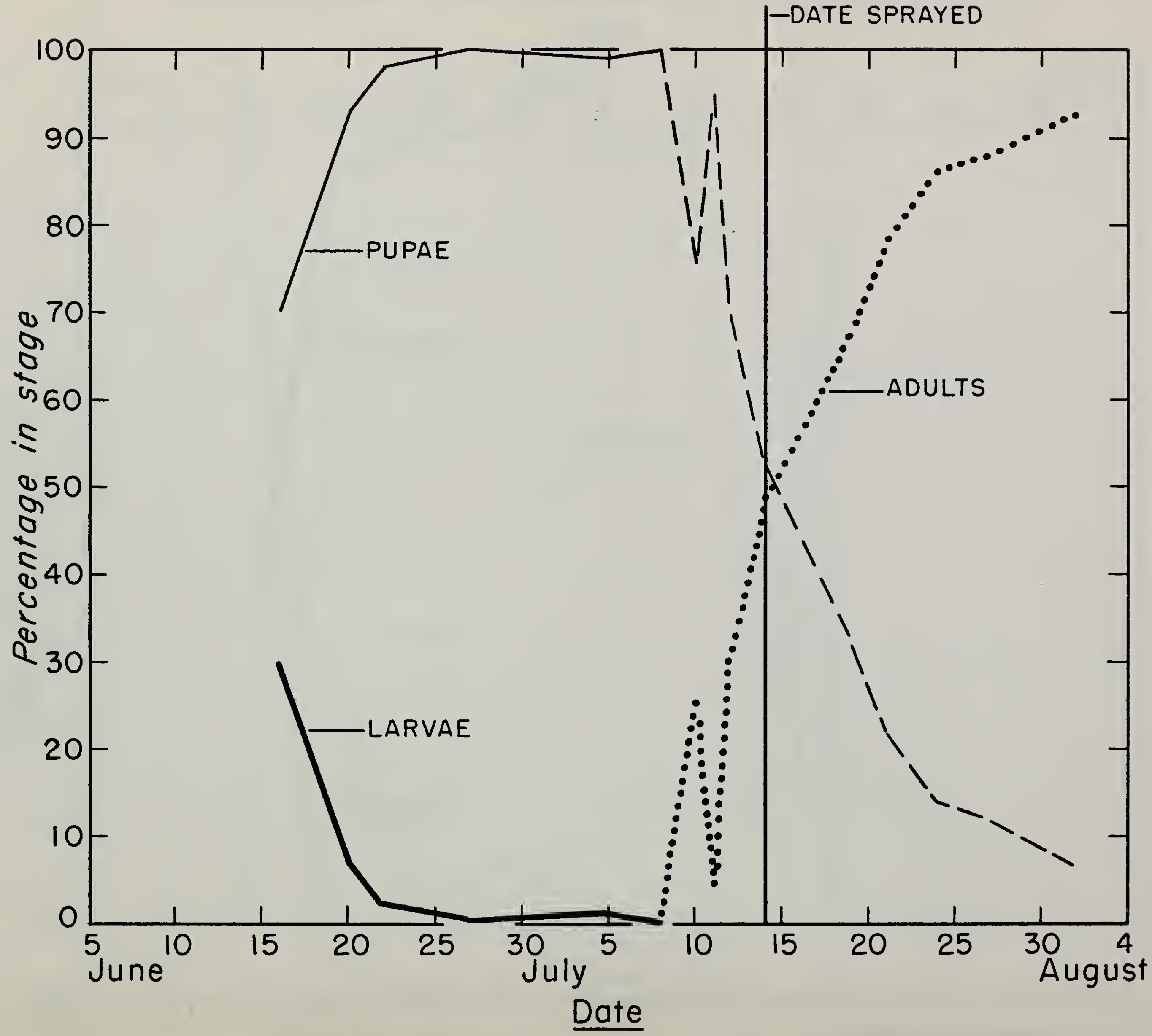

Figure 9.--Needle miner development at spray timing plot 12A.

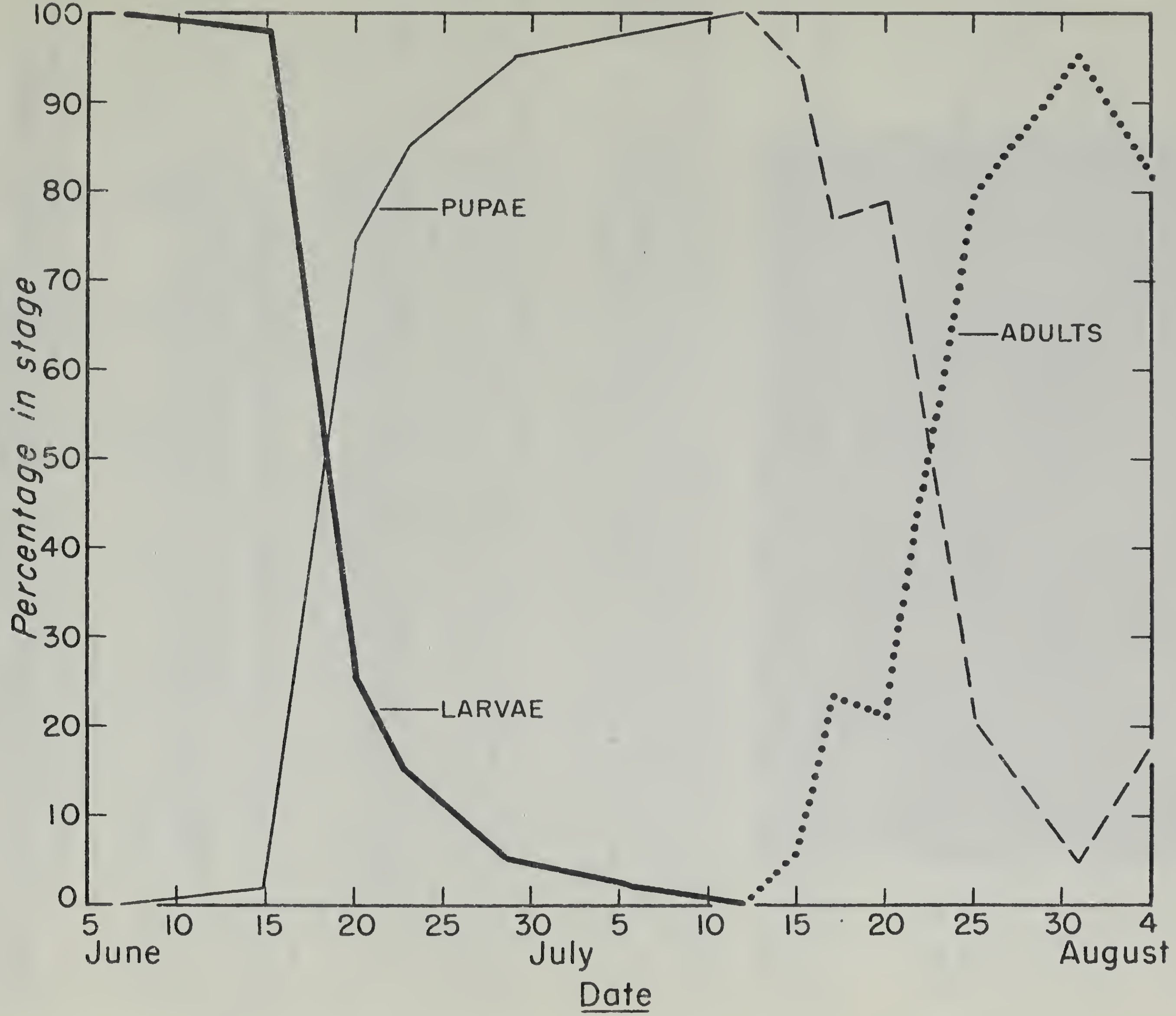

Figure 10.--Needle miner development at spray timing plot 15.

which show that the observed percent of emergence first reached the 25 percent level 28 days later, on July 12. The 5-day advance warning to begin spraying was given on July 7, when 1.0 percent emergence occurred.

Provisions were made in the project plan for suspending spraying in areas not sprayed within 15 days after 1 or 2 percent emergence occurred. Treating was completed well before this in all areas; however, if this had not been the case, the plan specified that after 70 percent of the moths had emerged on these areas, samples of foliage would be examined daily for eggs. And after an average of over 50 eggs per 5-year tip were found, no further spraying would be done.

SPRAY OPERATIONS

The operational phases of the 1961 needle miner control project are thoroughly described elsewhere,[6] and will be touched on here only to round out the picture of the project.

Formulation, distribution, and storage of the insecticide was handled by the Niagara Chemical Division, Food Machinery and Chemical Corporation, Fresno, California. Selected lots of the insecticide were sampled and the samples analyzed by Coast Laboratories, Inc., Fresno, to determine whether the spray met specifications.

Aetna Helicopters, Inc., Etna, California, furnished the spraying services for the project under contract with the Park. One Alouette and two Hiller 12-E aircraft (figure 11) were provided, along with three pilots and three mechanics. The spraying equipment and boom arrangements were similar in all three aircraft. The tanks on both Hillers were slung on either side of the fuselage and connected by a bypass hose running beneath the fuselage. The Alouette spray tank occupied the center section of the fuselage aft of the passenger compartment along with the fuel tank. All three spray systems were equipped with electrical centrifugal pumps. "Teejet" nozzles and check valves were used throughout.

The helicopters were calibrated at the start of the project in accordance with standard procedures, as given by Isler.[7] Table 2 lists the pertinent data.

6/ Thompson, T. R. and Orr, J. L. Lodgepole needle miner project, Tenaya Lake-Tuolumne Meadows, July 1961. Office report, Yosemite National Park, California. 18 pp., illus. (typed).

7/ Isler, D. A. 1958. Notes on some items involved in checking contract spray planes. U. S. Forest Serv., Forest Insect Laboratory, Beltsville, Maryland. 5 pp. (processed).

Figure 11.--Alouette (left) and Hiller 12-E helicopters used in lodgepole needle miner spraying, Yosemite, 1961.

Table 2.--Spray equipment data and performance in calibration tests, Yosemite, July 12-13, 1961 (dosage 10 gals./acre)

Aircraft	Boom length	Boom diameter	Nozzles	System pressure	Speed	Flow rate	Nominal swath width
	Feet	Inches	Number	P.s.i.	M.p.h.	Gal./min.	Feet
N-513 (Alouette)	$27\frac{1}{2}$	$1\frac{1}{2}$	1/ 42	40	60	82	68.3
N-5339V (Hiller)	$23\frac{1}{2}$	$1\frac{1}{2}$	2/ 35	40	60	40	33.3
N-5355V (Hiller)	$23\frac{1}{2}$	$1\frac{1}{2}$	2/ 37	40	60	35	29.2

1/ Spraying Systems Co. #8020, D-6 discs, directed downward.

2/ Spraying Systems Co. #8027 (plastic), D-8 discs, directed downward.

In order to check spray coverage during spraying operations, Park crews established lines of oil-sensitive cards throughout the control area, at the rate of about two cards per 20 acres. Radios were installed in the aircraft, permitting communications between the pilot, men on the ground in the area being treated, and the heliports. When occasional misses in the spray application were noted, often they could be rectified while the pilot was still treating the same area.

The spray was applied during the period July 13-18. Daily operations lasted from about 5:30 a.m. to 10:00 a.m.; rising winds and unstable air currents usually kept the spray droplets from settling satisfactorily after 10:00 a.m. The Hillers consistently carried 80 gallons and the Alouette 110 gallons of spray.

MEASURING THE EFFECTS OF SPRAYING

The effects of the treatment on the needle miner population were measured in several ways. Most of the emphasis was put into sequential sampling of the population, using essentially the system devised by Stevens and Stark.[8] This system involved establishing a large number of plots throughout the sprayed area and sampling before and after spraying to obtain population estimates. The second method was to sample the population in selected trees on sprayed and unsprayed areas before and after treatment, and compute the percent control by Abbott's formula. The third method, which gave an indication of the effectiveness of the work soon after spraying operations were completed, involved sampling the egg population on sprayed and unsprayed areas. Finally, the effects of the spray on the moths themselves were evaluated qualitatively by setting up a number of catch-cloths in treated and untreated areas, and collecting the insects which fell upon them.

SEQUENTIAL SAMPLING

As previously explained, the sequential sampling method of measuring the results of control involved establishing sample plots before and after spraying and obtaining estimates of the needle miner population on each plot at known levels of confidence. With this method the plots are chosen in whatever pattern conditions dictate, and in this case they were more or less scattered throughout the area (figures 12 and 13). Most of them were located in the treated area but some were in outlying untreated areas. In the precontrol sampling, done in the fall of 1960 and during June and early July 1961, 46 plots were taken; in the post-control sampling, October 9 to 13, 1961, the number taken was 54.

8/ Stevens, Robert E. and Stark, R. W. Sequential sampling for the lodgepole needle miner, *Evagora milleri* (Busck). Jour. Econ. Ent. (in press).

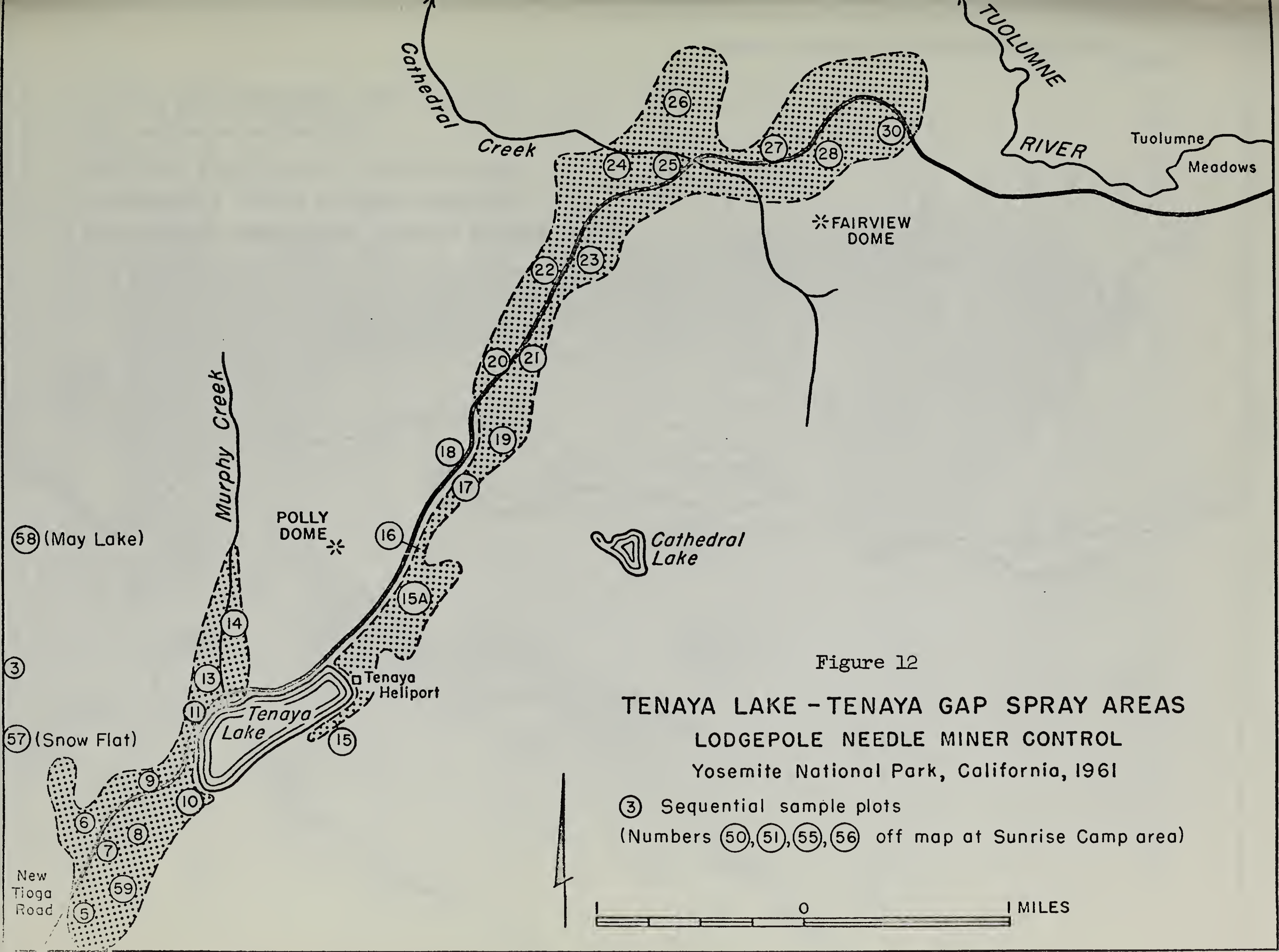

Figure 12

TENAYA LAKE - TENAYA GAP SPRAY AREAS
LODGEPOLE NEEDLE MINER CONTROL
Yosemite National Park, California, 1961

(3) Sequential sample plots
(Numbers (50),(51),(55),(56) off map at Sunrise Camp area)

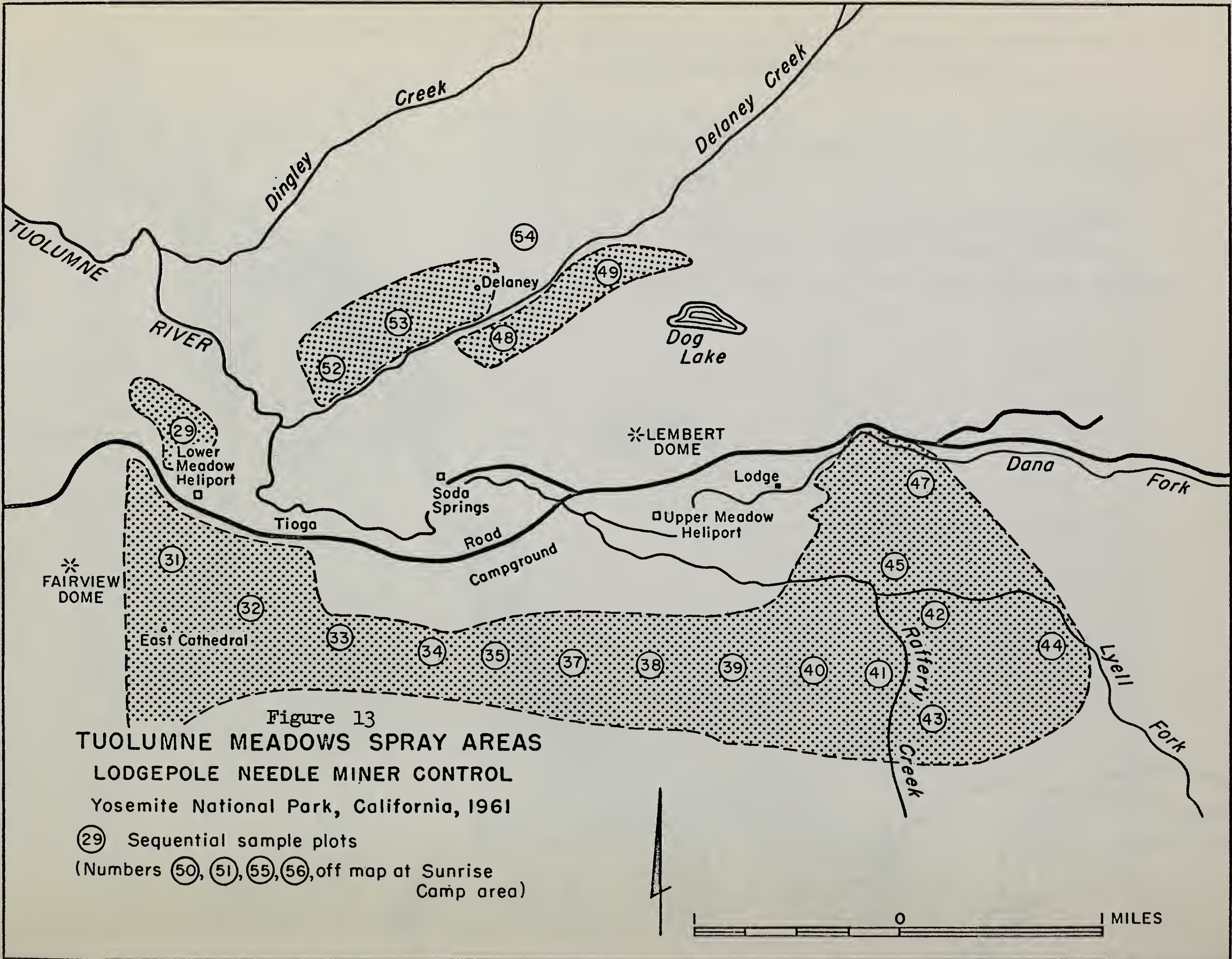

Figure 13

TUOLUMNE MEADOWS SPRAY AREAS

LODGEPOLE NEEDLE MINER CONTROL

Yosemite National Park, California, 1961

29 Sequential sample plots

(Numbers 50, 51, 55, 56, off map at Sunrise Camp area)

Four degrees of infestation are recognized with this sampling system:

Light - population less than 4 insects per whorl of needles.

Medium - population greater than 6 but less than 11.

Heavy - population greater than 13 but less than 18.

Very heavy - population greater than 20.

Light and medium populations are below the level expected to cause tree mortality, but continued heavy and very heavy populations of the magnitude are expected to result in mortality. Population estimates obtained with this system can be considered accurate at the 90 percent confidence level.

In using this technique the samplers randomly clipped at least one tip containing the last 2 years' foliage from a minimum of 20 trees at each plot. The last two whorls of needles were separated and the number of living insects in each counted. The number of samples taken per plot was variable, for the number of tips needed to arrive at a decision about the degree of infestation on a plot depends on the intensity of the infestation at that particular location. All of the counting was done in the field and the number of insects in each tip was accumulated on a field table (derived from the sequential graph) until a "decision area" was reached and the plot classified (figure 19, appendix). Sampling then ceased. In the precontrol samples, infested needles containing larvae were tapped to induce larval movement; those able to move quickly were counted as living insects. Pupae also were counted as living insects. In the postcontrol samples, mines of the newly established larvae were counted as living insects.

MORTALITY SAMPLING

Data for estimating needle miner mortality due to spraying were obtained from 12 lines of sample trees, laid out so that seven would be in areas to be sprayed and five in unsprayed areas. One of the "spray" lines was in an area that ultimately was not treated, so the outcome was six lines sprayed and six unsprayed (figures 14 and 15). The lines were established by two-man crews during the period June 16 to July 11. All but two of the lines were laid out by June 23.

Each line consisted of five sample trees about five chains apart. The lines in the areas to be treated were run at right angles to the expected direction of the spray flights, and in all areas the lines were strung to aid in locating the trees during the postcontrol sampling. The trees were numbered and marked with red plastic tape. Four tips, one from each cardinal direction, were cut from about midcrown or 16 to 18 feet above ground from each sample tree. Each tip was cut long enough so that it contained at least the last 2 year's needles. The tips were put into 5- by 7-inch glassine envelopes and were taken to the field laboratory for examination.

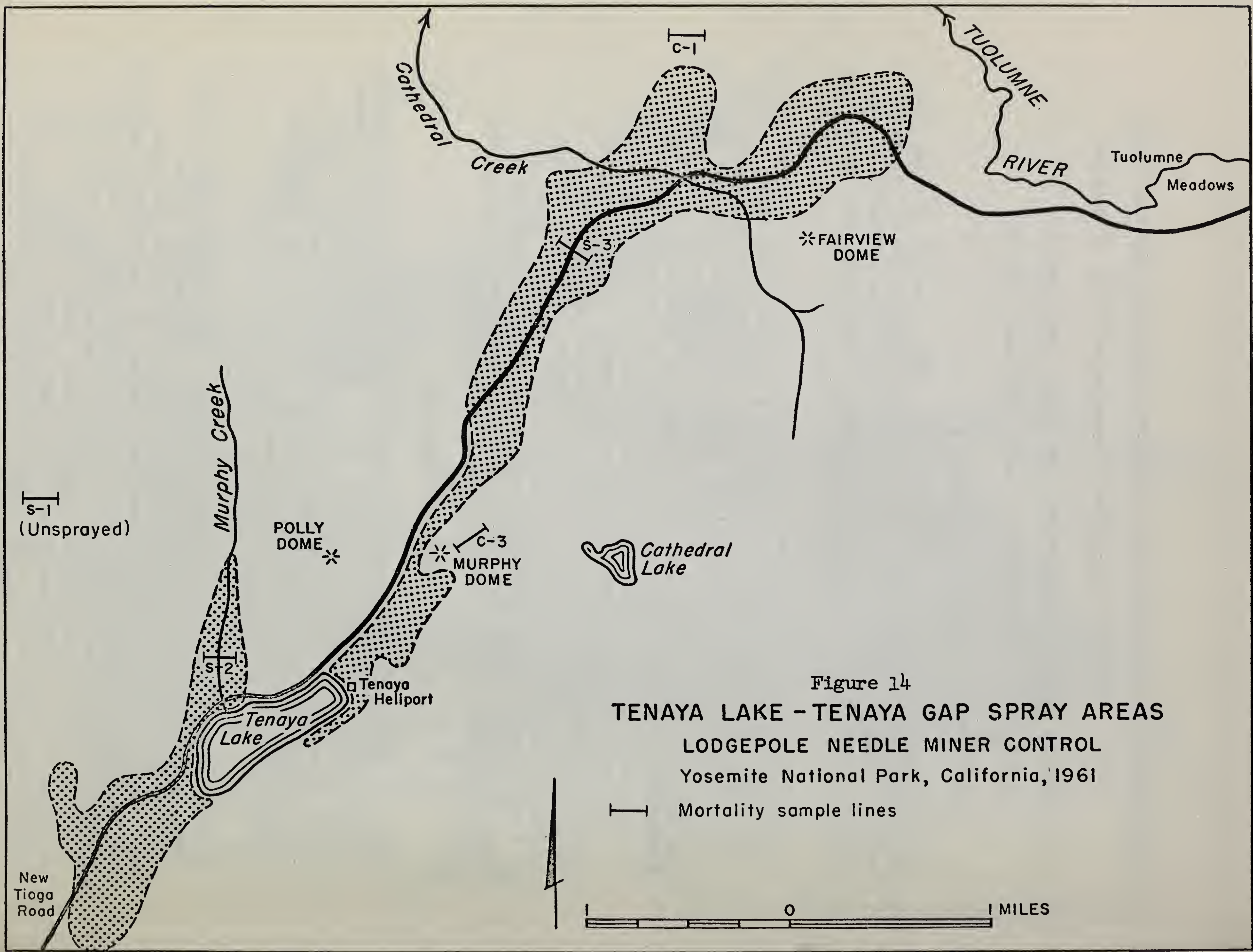

Figure 14
TENAYA LAKE - TENAYA GAP SPRAY AREAS
LODGEPOLE NEEDLE MINER CONTROL
Yosemite National Park, California, 1961

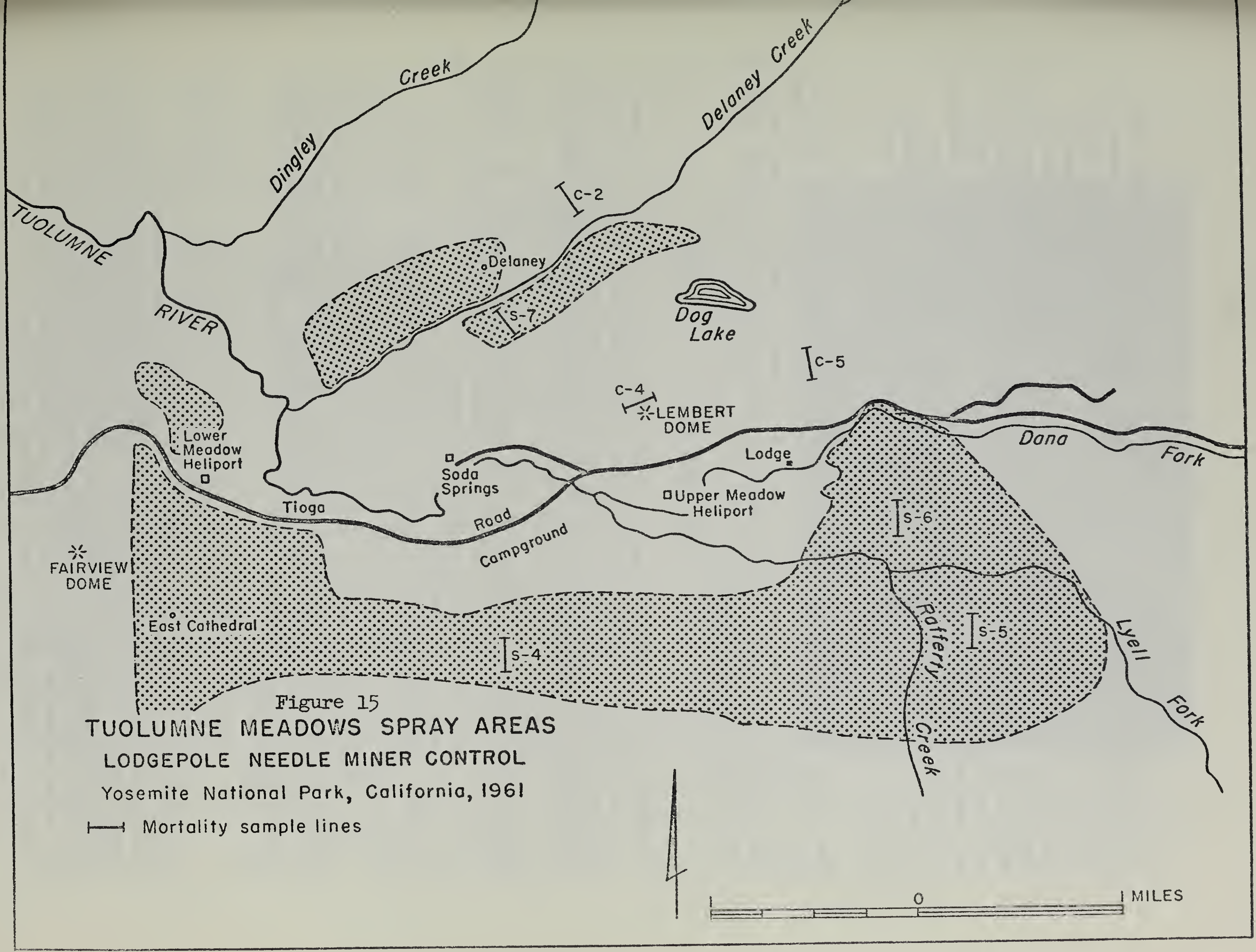

Figure 15

TUOLUMNE MEADOWS SPRAY AREAS

LODGEPOLE NEEDLE MINER CONTROL

Yosemite National Park, California, 1961

The precontrol survey was made between June 16 and July 23 when both larvae and pupae of the needle miner were present. In this survey 10 needles were drawn at random from the 1959 and 1960 foliage on each tip after the tips were brought into the laboratory. The number of mined needles was determined by eye, and the insects were dissected from their mines with a pin or teasing needle, under a binocular microscope, and classified as live or dead. Healthy larvae could generally be stimulated to move with a pin prick, and ability to move normally was used as the criterion for a live larva. It was generally necessary to puncture the pupal skin to determine whether or not a pupa was healthy; dried, shriveled specimens were called dead; full, healthy-appearing ones alive. Abandoned pupal cases were counted as living insects.

When the postcontrol survey was conducted October 9 to 13, the insects were early-instar larvae. This survey was done in essentially the same way as the preceding one except that the 10-needle samples were drawn from the 1960 and 1961 foliage and the larval mines were counted as each representing a living insect.

EGG SAMPLING

In order to get an early idea about the effectiveness of the treatment in preventing oviposition, egg sampling was undertaken soon after the spray was applied. Five of the plots used in determining needle miner development in the sprayed areas were selected for this work, and in nearby unsprayed areas five additional plots were established.

Sampling was started on August 1, and continued until August 11. Eight of the plots (four sprayed and four unsprayed) were sampled twice; the other two were sampled three times. At each location 20 tips (containing the last 5 years' foliage) were taken from 10 trees; that is, 2 tips per tree. This constituted a sample. The tips were taken from mid-crown, about 16 to 18 feet from the ground.

In the laboratory the samples were examined for potential oviposition sites. A potential oviposition site is a needle that has been mined one-third of its length or less, and then vacated. One hundred needles of this type and the number containing eggs was tallied, as were the total number of eggs.

DROPCLOTHS

Information on the immediate effects of spraying was gathered by collections from dropcloths from which needle miners and associated insects were recovered (figure 16). These cloths were set up just before spraying operations began, and collections were made from them daily for about 2 weeks. The cloths measured 3 x 6 feet in size, and they were suspended about 3 feet off the ground on 2- by 2-inch stakes. A rock or stick was put in the center of each cloth to help keep it

Figure 16.--Insects being collected from dropcloth, lodgepole needle miner control project, Yosemite, 1961.

from flapping and throwing the insects out. Deer repellent was used in the area in an attempt to reduce the incidence of damage to the cloths by these animals, and the stakes were sprayed with a residual insecticide to prevent ants from raiding the cloths. Altogether 13 dropcloths were set out--8 in treated areas and 5 in untreated areas (figures 17 and 18).

RESULTS AND DISCUSSION

The immediate results of spraying were impressive. Moths affected by the malathion dropped from the trees by the thousands, and where earlier shaking of limbs and trunks had dislodged swarms of the insects, comparable disturbances a day or two after spraying produced few to no moths. The surveys made later clearly demonstrated that this apparent reduction in the moth population was followed by drastic reductions in the number of offspring that became established in the sprayed areas.

Egg sampling indicated that almost 91 percent fewer eggs were laid in the sprayed areas than in the unsprayed ones (table 3); and only one-fifth as many egg sites were occupied in the former as in the latter.

Sampling selected trees before and after spraying to determine the population reduction showed equally good results. In the treated area the mean number of needle miners per sample decreased from 2.28 before

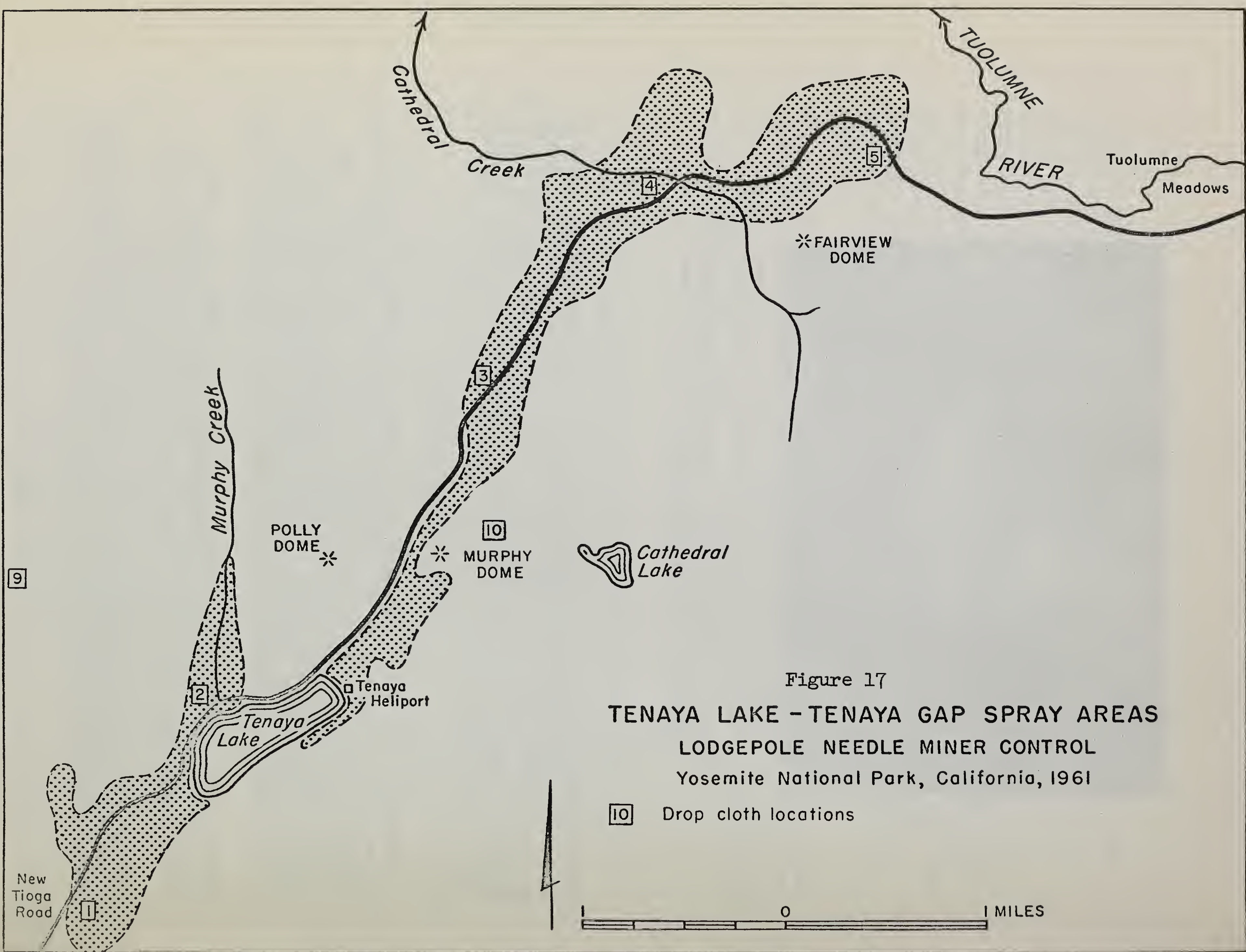

Figure 17

TENAYA LAKE - TENAYA GAP SPRAY AREAS

LODGEPOLE NEEDLE MINER CONTROL

Yosemite National Park, California, 1961

10 Drop cloth locations

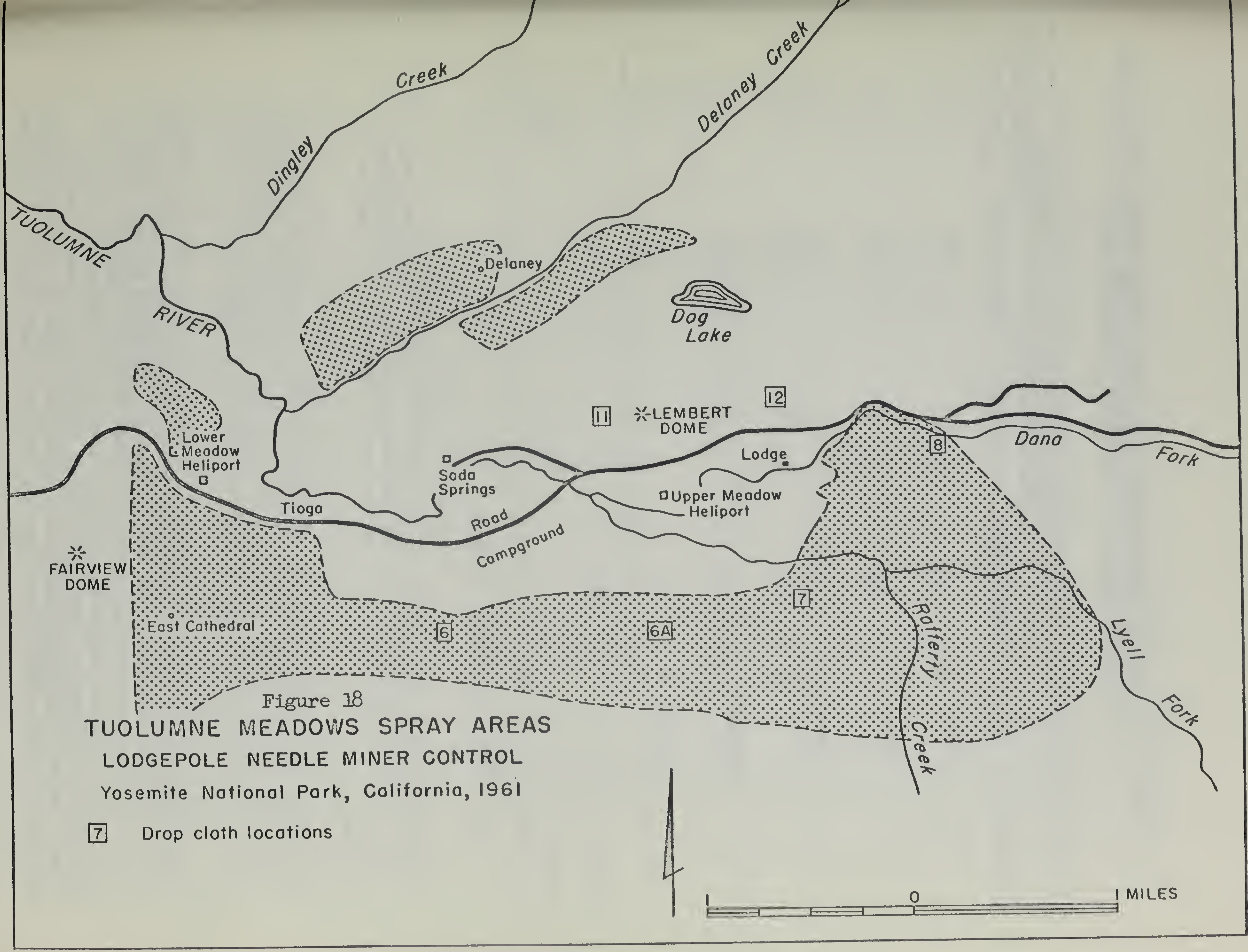

Figure 18

TUOLUMNE MEADOWS SPRAY AREAS

LODGEPOLE NEEDLE MINER CONTROL

Yosemite National Park, California, 1961

$\boxed{7}$ Drop cloth locations

Table 3.--Number of needle miner eggs laid and potential oviposition sites occupied in sprayed and unsprayed areas

Location[1]	Date	Sprayed: Number eggs	Sprayed: Percent sites occupied	Unsprayed: Number eggs	Unsprayed: Percent sites occupied
2A	August 1	41	12	360	35
	8	63	13	361	21
4	August 1	9	2	249	51
	7	26	5	437	57
7A	August 2	42	6	231	29
	8	0	0	131	19
	11	12	6	247	27
9	August 2	10	5	153	25
	9	23	5	167	28
12	August 4	11	4	104	20
	9	9	4	156	25
Totals		246		2,596	
Average			5.6		30.6

1/ Refer to figures 1 and 2.

spraying to 0.34 afterwards; in the untreated area the number increased from 1.55 to 2.35 (table 4). The mortality due to the spray alone, computed from these data through the use of Abbott's formula, was 90 percent.

The results of the sequential sampling (table 5) showed that all but one of 46 plots sampled after spraying in the main body of the control area were in the "light infestation" category. Before spraying only 10 out of 46 plots in this area were classed as "light."

The only exception to this generally favorable picture was at Sunrise Camp, where the results of sequential sampling indicated that little or no benefits resulted from the treatment. Inasmuch as this unit, totaling 56 acres, is considerably removed from the main body of the spray area, the treatment was not observed on the ground by project personnel, nor were oil-sensitive cards laid out to check coverage. Thus, the exact area treated is not known, and some of the postcontrol sampling may have been done in stands that were not sprayed. Another

Table 4.--Number of needle miners in mortality samples before and after spraying

Sample line	Number of 10-needle samples: Prespray	Number of 10-needle samples: Postspray	Number live insects: Prespray	Number live insects: Postspray	Percent control
Treated					
S-2	20	20	65	7	
S-3	20	20	34	4	
S-4	20	20	56	2	
S-5	20	20	27	6	
S-6	20	20	48	6	
S-7	20	20	43	16	
Totals	120	120	273	41	
	Mean no. insects per sample		2.28	0.34	90
	Standard error/mean		±0.14	±0.06	
Untreated					
S-1	20	20	46	77	
C-1	20	20	32	31	
C-2	20	20	32	42	
C-3	20	20	33	49	
C-4	20	20	29	52	
C-5	20	20	14	31	
Totals	120	120	186	282	
	Mean no. insects per sample		1.55	2.35	
	Standard error/mean		±0.13	±0.22	

possible reason for these poor results is that several small discontinuous areas were treated; the camp itself was omitted. Thus, moths from the surrounding unsprayed area may have been able to overcome the effects of the treatment. This did not happen in previous tests involving small isolated areas; however, the configurations of the areas involved at Sunrise Camp may have been a factor. These were generally long, narrow strips, bounded on at least one side by unsprayed, infested timber. Whatever the cause for the failure of the treatment in this instance, it should be recognized that the omitting of the camp itself tended to defeat the purposes of spraying.

Table 5.--Needle miner populations and class of infestation on sequential sampling plots, before and after spraying

	Precontrol 1/		Postcontrol			Precontrol		Postcontrol	
Plot	Class	No. insects/ no. whorls	Class	No. insects/ no. whorls	Plot	Class	No. insects/ no. whorls	Class	No. insects/ no. whorls
1	Not used				31	L-M	205/42	L	202/63
2	Not used				32	M	381/52	L	73/37
3	VH	337/7	Not sampled		33	M	318/41	L	63/35
4	H-VH	564/32	H	792/55	34	M	308/39	L	0/22
5	H	750/53	L	15/26	35	M	282/34	L	41/31
6	M	344/38	L	198/62	36	Not used			
7	H-VH	599/32	L-M	419/65	37	H	735/52	L	3/23
8	L-M	466/265	L	240/70	38	M	358/39	L	15/26
9	L-M	274/40	L	43/31	39	M	345/46	L	5/23
10	M	285/35	L	83/39	40	M	293/34	L	4/23
11	M-H	348/46	L	43/31	41	M-H	470/46	L	28/28
12	L-M	124/32	L	11/25	42	M	19/26	L	33/37
13	M	422/62	L	32/29	43	M	328/43	L	20/26
14	M	342/38	L	8/24	44	L	35/29	L	15/25
15	L-M	136/32	L	26/28	45	M	314/36	L	4/23
16	L-M	73/32	L	4/23	46	Not used			
17	Not sampled		L	5/24	47	L	104/43	L	0/22
18	M	291/34	L	74/37	48	M	291/34	L	11/25
19	L	214/65	L	25/28	49	M	348/38	L	8/24
20	L	80/38	L	1/22	50	M	258/33	H	2/4/ 581/39
21	L	76/38	L	3/23	51	M	329/37	M	3/4/ 460/69
22	L	38/30	L	4/23	52	Not sampled		L	42/31
23	L-M	342/64	L	2/23	53	Not sampled		L	16/26
24	L	91/41	L	5/24	54	Not sampled		L-M	2/ 195/49
25	L-M	268/65	L	3/23	55	Not sampled		M	2/ 278/33
26	L	67/36	L	0/22	56	Not sampled		M	2/ 433/54
27	L	15/25	L	2/23	57	Not sampled		L-M	2/ 218/36
28	M	317/41	L	8/24	58	Not sampled		M	2/ 335/42
29	M	340/38	L	11/25	59	Not sampled		L	41/31
30	L	166/56	L	58/34					

1/ Classes are: L (light), M (medium), H (heavy), VH (very heavy). Numbers of insects and whorls needed to arrive at a decision have no statistical significance; they are included only as a matter of interest.

2/ Unsprayed check.

3/ Probably not sprayed.

4/ Sunrise Camp.

Deer did considerable damage to the dropcloths, reducing the number of collections and making the value of using deer repellent around these installations seem questionable. Nevertheless, a large number of species and forms of insects were collected in the dropcloths, both in the treated and untreated areas (table 6).

As in 1959, the only insects appearing with much regularity were the needle miner and one of its principal parasites, Copidosoma sp. The incidences of these species in the collections are given in tables 7 and 8.

As the data in these tables show, the increase in number of insects collected in some dropcloths (e.g., 5, 6, and 6A) does not coincide precisely with the spray date. This is probably the result of our not knowing the exact date that the trees near each dropcloth were sprayed, or the collection having been made early in the day, before the area was sprayed. One presumably unsprayed area, where trap 10 was located, may have received enough drift to cause insect mortality, judging from the data. Oil-sensitive cards were not set out at these installations to show whether or not they were covered, and if so, on what date. It would be desirable to use such cards in conjunction with dropcloths if the latter are used in the future.

The general objective of spraying all of the control units when 25 percent emergence occurred was not always met; as a matter of fact, it was often not. The simple logistics of applying heavy dosages of insecticide to extensive areas in which insect development proceeds at a more or less uniform rate made it difficult to meet this goal.

Getting the spraying operation underway a day or two earlier might have helped, although this involves some problems. It is difficult enough to accurately determine when 1 percent emergence has occurred, and it seems improbable that one could get a solid starting date earlier than that. One place to take up the slack is in the 5-day lead time, and the possibility of shortening this might be considered in future control work.

The adequacy of the entomological work done on a project of this sort results not only from the careful planning done ahead of time, but also from having enough manpower to carry the plans out. Stevens and Sartwell were in residence on this project full time, from June 5 until after the spraying was completed, leaving around July 20. Schymeinsky began work on June 14 and remained until mid-August. After the spraying was completed he continued to collect from the dropcloths, and subsequently did the egg sampling. Some of the pre-control survey work was done in the fall of 1960; the remainder of it was interspersed with needle miner development studies, installation of the dropcloths, etc., in June and July 1961. The postcontrol mortality sampling and sequential sampling took six men 3 days to complete.

Table 6.--Arthropod species or forms collected in dropcloths in sprayed areas, lodgepole needle miner control, Yosemite 1961

Group	No. species or forms collected	Group	No. species or forms collected
Hymenoptera		Coleoptera	
Chalcidoidea	26	Buprestidae	4
Braconidae	11	Dasytidae	1
Ichneumonidae	7	Melandryidae	2
Cynipoidea	1	Cantharidae	2
Formicidae	3	Dermestidae	2
Platygasteridae	1	Coccinellidae	4
Symphyta	2	Hydrophilidae	1
		Staphylinidae	2
Diptera		Anobiidae	2
Chironomidae	18	Lathrydiidae	1
Cecidomyidae	3	Curculionidae	5
Anthomyiidae	1	Leiodidae	1
Asilidae	1	Anthicidae	1
Otitidae	1	Scolytidae	1
Sciaridae	2	Elateridae	1
Simuliidae	1		
Phoridae	3	Lepidoptera	
Agromyzidae	3	Gelechiidae	4
Empididae	8	Tortricoidea	1
Rhagionidae	1	Heliozelidae	1
Mycetophilidae	1	Pyralidae	1
Tachinidae	4		
Culicidae	2	Homoptera	
Chloropidae	1	Unknown	3
Psychodidae	1	Cicadellidae	4
Lauxaniidae	1	Aphidae	3
Pididae	1	Fulgoridae	2
Ceratopogonidae	1	Lygaeidae	1
Clusiidae	1	Psyllidae	2
Pipunculidae	1		
Bibionidae	2	Heteroptera	
Tipulidae	2	Miridae	12
Thereoidae	1	Anthocoridae	3
Neuroptera		Plecoptera	1
Raphididae	1		
Hemerobiidae	1	Trichoptera	2
Coniopterygidae	1		
Unknown immature forms	4	Ephemerida	2
Psocoptera	6	Thysanoptera	1
		Arachnida	2

Table 7.--Numbers of lodgepole needle miners collected in dropcloths, by trap location

Date	Sprayed									Unsprayed			
	1	2	3	4	5	6	6A	7	8	9	10	11	12
July 12	6	14	--	--	2	3/	3/	3/	3/	--	11	3/	3/
13	4	4/116	1	--	--	3/	3/	--	3/	3	12	3/	3/
14	4/114	278	4/22	1	2	6	4/5	4/	2	0	231	2	3
15	345	44	46	4/	4/10	1	1	171	4/1	3	63	5	6
16	10	21	19	61	145	8	9	236	223	7	56	3	6
17	18	21	32	15	305	171	465	97	41	3	34	8	8
18	14	19	35	14	76	4/121	59	69	34	2	47	12	31
19	15	14	43	14	--	52	1/	2	34	16	24	7	25
20	20	13	23	9	35	15	24	21	9	9	36	5	12
21	17	44	36	9	24	11	29	21	12	8	49	13	15
22	--	--	--	--	--	--	--	--	--	--	--	--	--
23	--	--	--	--	--	--	--	--	--	--	--	--	--
24	99	38	114	25	1/	1/	1/	92	45	23	169	23	--
25	14	18	1/	9	1/	1/	7	20	7	9	41	4	30
26	5	9	1/	2	4	2/	1	1	3	2	17	13	27
27	8	4	2/	1	2	--	3	0	1	4	17	11	26
28	7	3	--	--	6	--	1	4	0	--	12	4	35

1/ Cloth torn or missing.

2/ Cloth torn. Discontinued.

3/ Not yet established.

4/ Date presumed sprayed.

Table 8.--Numbers of *Copidosoma* sp. collected in dropcloths, by trap location

Date	Sprayed									Unsprayed			
	1	2	3	4	5	6	6A	7	8	9	10	11	12
July 12	--	--	--	--	--	3/	3/	3/	3/	--	--	3/	3/
13	--	4/	--	--	--	--	--	--	3/	--	--	3/	3/
14	4/	--	4/	--	--	--	4/	4/	4/	--	--	--	--
15	--	--	--	4/	4/	--	--	--	1	--	--	--	--
16	--	--	--	--	--	--	--	--	1	--	--	--	--
17	--	--	--	--	--	--	--	--	1	--	--	--	--
18	--	7	--	--	--	4/	4	--	--	--	--	--	--
19	--	21	--	--	--	--	1/	--	--	3	--	--	--
20	--	22	--	--	1	--	2	--	--	4	--	--	1
21	--	56	--	--	1	--	4	--	1	1	--	--	--
22	--	--	--	--	--	--	--	--	--	--	--	--	--
23	--	--	--	--	--	--	--	--	--	--	--	--	--
24	16	101	6	1	1/	1/	1/	4	1	13	32	1	--
25	25	70	1/	4	1/	1/	2	3	1	4	13	--	--
26	9	50	1/	13	7	2/	1	2	--	15	14	--	--
27	22	61	2/	10	7	--	4	4	3	19	17	4	2
28	7	41	--	13	10	--	4	--	1	3	16	3	2

1/ Cloth torn or missing.

2/ Cloth torn. Discontinued.

3/ Not yet established.

4/ Date presumed sprayed.

The most time-consuming portions of the job were the precontrol survey work and developing the data needed to time the operation for maximum effectiveness. The extensive nature of the project meant that a considerable amount of time was used in collecting needle miner development samples. It was felt that during June and the first half of July, a fourth man could have been used effectively on the entomological phases of the work.

Now, what does the future hold for the needle miner control area? We believe that the main body of lodgepole treated in 1961 will not need further attention until 1964, at which time a survey should be made to determine the status of the infestation. The Sunrise Camp area should be surveyed in more detail in 1962, and if it still appears advisable to do direct control to save trees there, plans should be laid to spray it in 1963. Similarly, the units sprayed in 1959 that were not retreated in 1961 should be surveyed in 1962. There are some indications that heavy populations now exist in portions of the stands sprayed in 1959 to control the larvae, and it may be advisable to treat these during the moth stage in 1963.

In addition, as Thompson and Orr[9/] suggest, surveys should be made of the May Lake trail parking area and Glen Aulin to determine if the stands in these locations are seriously threatened. The Elizabeth Lake basin and the Lyell Fork areas should also be included in the survey.

9/ op. cit.

APPENDIX

Table 9.--Proportion of needle miners in different developmental stages on sample plots by dates, June to August 1961

Date	Larvae	Pupae	Adults
	- - - -	Percent	- - - -
	Plot 1 1/		
June 8	100		
14	99	1	
16	86	14	
19	61	39	
21	16	84	
22	20	80	
26	10	90	
30	8	92	
July 12		71	29
14		49	51
17	1	41	58
18		21	79
20		8	92
24		5	95
26		8	92
28		3	97
	Plot 2		
June 8	100		
13	100		
15	83	17	
19	42	58	
23	10	90	
29	12	88	
July 4	6	94	
9		99	1
10		93	7
11		91	9
13		59	41
14 2/			
	Plot 2A		
July 10		82	18
11		84	16
13 1/		51	49
	Plot 3		
June 8	100		
13	94	6	
15	72	28	
19	12	88	
21	7	93	
28	1	99	
July 3	7	93	
7		99	1
8		78	22
9	2	74	24
10		84	16
11		76	24
13 2/			
17		10	90
18		10	90
19		8	92
21		11	89
25		8	92
27		8	92
	Plot 3A		
July 9		78	22
11		64	36
14 2/			
	Plot 3B		
July 10		80	20
11		74	26
13 2/			

1/ Plot not sprayed.

2/ Date presumed sprayed.

Table 9.--Continued:

Date	Larvae	Pupae	Adults
	- - - -	Percent	- - - -
	Plot 4		
June 8	100		
13	94	6	
15	73	27	
19	17	83	
26	2	98	
30	2	98	
July 6	1	99	
9		92	8
11		85	15
13	2/		
	Plot 5		
June 6	100		
8	100		
13	100		
15	64	36	
19	19	81	
21	12	88	
28	11	89	
July 3	6	94	
8	8	91	1
10	5	83	12
11	4	81	15
13	2/		
	Plot 5A		
July 10	9	89	2
11	6	80	14
14	2/		
	Plot 6		
June 6	100		
8	100		
13	100		
15	78	22	
19	48	52	
23	13	87	
29	13	87	
July 4	7	93	
9	3	97	
12		98	2
	Plot 6 (Continued)		
July 13		91	9
14	2/		
18		46	54
20		41	59
24		15	85
26		17	83
28		8	92
31		3	97
	Plot 7		
June 6	100		
8	100		
13	98	2	
14	86	14	
16	59	41	
19	33	67	
26		100	
30	1	99	
July 6	4	96	
8		97	3
10		97	3
13		56	44
14		66	34
15	2/	40	60
	Plot 8		
June 6	100		
8	100		
13	84	16	
14	80	20	
16	52	48	
19	3	97	
21	4	96	
28	2	98	
July 3		100	
4	3	97	
6	1	99	
7	2	98	
9	1	98	1
12		58	42
15	2/		

Table 9.--Continued:

Date	Larvae	Pupae	Adults
	- - - -	Percent	- - - -
	Plot 8A		
June 14	75	25	
July 15	2/		
	Plot 8B		
June 14	75	25	
July 15	2/		
	Plot 8C		
June 14	74	26	
July 15	2/		
	Plot 9		
June 6	100		
8	100		
13	99	1	
16	38	62	
19	25	75	
23	2	98	
29	7	93	
July 4	1	99	
8		100	
9		98	2
13		85	15
14		68	32
15	2/		
18		23	77
19		14	86
21		16	84
25		8	92
27		6	94
31		5	95
	Plot 9A		
July 13		71	29
15	2/		
	Plot 9B		
July 13		69	31
16	2/		
	Plot 9C		
July 13	2/	49	51
	Plot 10		
June 15	57	43	
19	12	88	
21	8	92	
26	2	98	
July 4	1	99	
9	1	94	5
12	1	48	51
18	2/		
	Plot 11		
June 15	54	46	
19	6	94	
23	1	99	
29		100	
July 3		100	
6		97	3
7		98	2
8		100	
10		97	3
13		50	50
15		40	60
18	2/	15	85
20		9	91
24		11	89
26		9	91
	Plot 12		
June 15	61	39	
16	48	52	
19	19	81	
21	9	91	
28	2	98	
30	3	97	
July 3	1	99	
6	3	97	
8		100	
10	1	98	1
13		90	10
14	2/		
15		61	39

Table 9.--Continued:

Date	Larvae	Pupae	Adults
	- - - -	Percent	- - - -
	Plot 12A		
June 16	30	70	
20	7	93	
22	2	98	
27		100	
July 5	1	99	
8		100	
10		75	25
11		95	5
12		70	30
14	2/	52	48
19		32	68
20		22	78
24		14	86
27		12	88
Aug. 1		7	93
	Plot 13		
June 14	79	21	
16	35	65	
20	1	99	
22	3	97	
27	2	98	
July 5	2	98	
7	1	98	1
10		90	10
11		88	12
12		73	27
13	2/		
	Plot 14		
June 15	49	51	
16	35	65	
20	1	99	
22	2	98	
27	3	97	
July 5		100	
7	1	98	1
10		90	10
12		67	33
16	2/		

Date	Larvae	Pupae	Adults
	- - - -	Percent	- - - -
	Plot 15		
June 7	100		
15	98	2	
20	26	74	
23	15	85	
29	5	95	
July 6	2	98	
12		100	
14		96	4
15		94	6
17		77	23
18	2/		
20		79	21
25		21	79
31		5	95
Aug. 4		18	82
	Plot 15A		
July 14		80	20
15		71	29
17		54	46
18	2/		
	Plot 16		
July 8		97	3
10		99	1
12	1	64	35
14		52	48
16	2/		
	Plot 16A		
July 10		98	2
12	2	74	24
14		50	50
16	2/		
	Plot 17		
July 13		99	1
16		95	5
19	2/		
	Plot 18		
July 13		99	1
16		95	5
19	2/		

Figure 19.--Sequential sampling field table - lodgepole needle miner

Area____________ Plot_______________ Infestation class_______

Date____________ Sampler____________

Number whorls sampled (n)	Cumulative number live insects (Σx)		1		2		3		4		5		6	
22			1										528	
23			5										547	
24			10										566	
25			15										585	
26			20										604	
27			25										623	
28			30										642	
29			35										661	
30			40										680	
31			45										699	
32			50		270		274		494		498		718	
33			55		275		286		506		517		737	
34			60		280		298		518		536		756	VERY HEAVY INFESTATION
35		LIGHT INFESTATION	65	CONTINUE SAMPLING	285	MEDIUM INFESTATION	310	CONTINUE SAMPLING	530	HEAVY INFESTATION	555	CONTINUE SAMPLING	775	
36			70		290		322		542		574		794	
37			75		295		334		554		593		813	
38			80		300		346		566		612		832	
39			85		305		358		578		631		851	
1/ 40			90		310		370		590		650		870	

1/ Form used in project was continued to n = 75.